CORE
Metadata, citation and similar papers at core.ac.uk
Provided by Digital Repository @ Iowa State University

IOWA STATE UNIVERSITY
Digital Repository

Proceedings of the ARPA/AFML Review of Progress in Quantitative NDE, September 1976–June 1977

Interdisciplinary Program for Quantitative Flaw Definition Annual Reports

5-1978

Reliability by Design

W. J. Willoughby Jr.
United States Navy

Follow this and additional works at: http://lib.dr.iastate.edu/cnde_yellowjackets_1977


Part of the Materials Science and Engineering Commons

Recommended Citation
Willoughby, W. J. Jr., "Reliability by Design" (1978). *Proceedings of the ARPA/AFML Review of Progress in Quantitative NDE, September 1976–June 1977*. 2.
http://lib.dr.iastate.edu/cnde_yellowjackets_1977/2

This 2. Introductory is brought to you for free and open access by the Interdisciplinary Program for Quantitative Flaw Definition Annual Reports at Iowa State University Digital Repository. It has been accepted for inclusion in Proceedings of the ARPA/AFML Review of Progress in Quantitative NDE, September 1976–June 1977 by an authorized administrator of Iowa State University Digital Repository. For more information, please contact digirep@iastate.edu.

Reliability by Design

Abstract
Gentlemen, it is my privilege to spend a few minutes with you tonight. I'd like to thank ARPA, the Air Force, and the Rockwell Science Center for the invitation to share a little bit of what I call the "new look" in the Navy. I'm really here tonight on behalf of the Navy, and particularly on behalf of Admiral Michaelis who is the Chief of Naval Material. The story I have to tell you is one that I think you will find somewhat enlightening. I know you'll find some of it amusing, but I hope that the overall message will be that the Navy has undertaken a program to improve its fleet readiness and has undertaken it as a very serious proposition.

Keywords
Nondestructive Evaluation

Disciplines
Materials Science and Engineering

This 2. introductory is available at Iowa State University Digital Repository: http://lib.dr.iastate.edu/cnde_yellowjackets_1977/2

RELIABILITY BY DESIGN

W. J. Willoughby, Jr.
Assistant Deputy Chief of Naval Material
(Reliability and Engineering)

Headquarters Naval Material Command
Washington, DC 20360

With Introduction
by
Hans Vanderveldt
Department of the Navy
Naval Sea Systems Command

Good evening. The keynote address tonight addresses a topic in which all of you are extremely interested. That topic is reliability by design. To present to you some thoughts on the Navy's approach to this idea, we have with us probably the foremost authority in the Navy for the establishment of policy and programs in this area, a man who is the Deputy Chief of the Navy Materials Command for reliability and maintainability. Mr. Willis J. Willoughby is exceedingly well qualified for this position. He has some 22 years of experience that ranges from basic engineering to design to engineering management, a very important function itself, and prior to accepting this position with the Navy, he was Director of reliability, quality, control, and safety for the manned spaceflight program of the National Aeronautics and Space Administration's Apollo Program. It was the success of this program which brought Mr. Willoughby to the Navy's attention and to Admiral Isaac Kidd in particular. Admiral Kidd, who was the commander, the Chief of Naval Material, invited him to come with the Navy to establish the program, the policies, and the procedures necessary to improve the reliability and maintainability of our fleet afloat. He has been able to bring a new look to the Navy in this area quite successfully, and he is getting a lot of attention. He has formalized, and this is a very important step in the Navy, a new approach for building vehicles and issuing an instruction which deals with reliability of naval material. He has received the Apollo Group Achievement Award and the NASA Exceptional Service Medal. I think I have talked long enough, so without further delay, it is my privilege to introduce to you Mr. Willis J. Willoughby.

RELIABILITY BY DESIGN

W. J. Willoughby, Jr.
Assistant Deputy Chief of Naval Material
(Reliability and Engineering)

Headquarters Naval Material Command
Washington, DC 20360

Gentlemen, it is my privilege to spend a few minutes with you tonight. I'd like to thank ARPA, the Air Force, and the Rockwell Science Center for the invitation to share a little bit of what I call the "new look" in the Navy. I'm really here tonight on behalf of the Navy, and particularly on behalf of Admiral Michaelis who is the Chief of Naval Material. The story I have to tell you is one that I think you will find somewhat enlightening. I know you'll find some of it amusing, but I hope that the overall message will be that the Navy has undertaken a program to improve its fleet readiness and has undertaken it as a very serious proposition.

A story comes to mind that I think is appropriate to this particular gathering, especially since I've seen a number of you before in various places as you represent companies, universities, or the Government. This story came to me recently. It relates to an old lady who is getting ready to get on a train. She saw the conductor making signals to the engineer. The lady walked up to him and said she would like to know what he was doing. He was pretty grumpy and the train was late, so he turned to her and said, "Lady, when I do that kind of a thing, I'm telling the engineer to get the hell out of here." So with that, he walked off in a huff. The little lady got on the train and sat down. A little later, the conductor began thinking about it and realized that he had been a little rude. He decided he would apologize to her. As he approached the lady and started to say that he was sorry, she made the same signals he had made to the engineer. In some respects, I think that's the way I approach some of you--it's time to get the hell out of here.

Nondestructive testing came to me a long time ago and I never really knew what it was. My father was an executive with the Atlantic Coast Line Railroad. Back in the 30's, I can remember my pride when my father took me out to the railroad shops one day and showed me a thing called the Sperry Car. That's, of course, the device that the railroads run up and down the tracks to check the rails. I had never seen it. I took a little ride out on it. I didn't know what was so impressive about it except for its being so small. I could see papers being run through something and wiggles being made. From that, somebody was telling me, it was a remarkable thing. I later encountered the same kind of an experience, only this time it was much more serious.

On the Apollo program, we learned a lesson about titanium and methanol. As you know by now, titanium and methanol don't mix. We didn't know it at the time. One night at home I got a telephone call at 11:00 p.m., and it was similar to the story of the train, only they were telling me to get the hell out to Downey. A titanium tank had exploded. A launch tank had it on board. Actually, it was a dock tank, but nobody quite knew what had happened. We were all scared because we were approaching launch date. We didn't know what was really going on, but when we found out what happened we were even more scared because we heard of things for the first time called flaw sizes, growth rates, progression rates, all sorts of things--eventually termed stress corrosion. Most frightening to us at that time was that we had bought all the titanium tanks we were going to buy. So there we were with a buy of titanium tanks on our hands and an Apollo launch pretty nearly at hand.

A lot of excited people began to get into the act, and I found myself facing some very learned people who very quickly became even more learned about a thing called stress corrosion in titanium. They finally wound up convincing us that they understood the fracture mechanics well enough that they could tell us not only the flaw size, but the growth rate. We were being assured as we were putting that thing together on the pad that for every pressure cycle we put on it, the growth rate would be thus and so. The people would stand up in front of our flight readiness reviews and say the growth is thus and so, and when we get to the moon it will be this big, and when you get back home it will be this big. "But don't worry, fellows, it isn't going to hurt you," they said. That was news to me and I went home every night saying, "I wonder if those fools know what they're talking about?" I didn't know, NASA didn't know, but the more data we collected, the more we became convinced that that was what was happening.

We could live with a flaw of a particular size, and as a matter of fact, we did. Before every mission we flew, we determined what flaw sizes we had in the tanks and the projected time they were going to last and how many pressure cycles we could put on them. After that experience, I came to have a very deep appreciation for the science of stress corrosion, metal fatigue, and nondestructive testing. It was a "bath" that I had never taken before; it was a "bath" I never want to take again because it was a very worrisome thing for us all. There was just no way we could demonstrate completely that we were right. We had a very fine group of engineers and a very fine group of industrial support people who, I think, did an outstanding job; and we learned to live in their confidence. It was hard to do at first because we

weren't trained for that. When we had things that weren't right, we simply stomped them out.

With that memory in mind, I'd like to share with you tonight what I think to be an exciting evolution, or revolution, that's taking place within the Naval Material Command and within the Navy as a whole. I would like to bring to your attention what it can mean to the nondestructive test community, and later on will summarize some of the observations that I have made.

I came to the Navy at their invitation kicking and screaming all the way. I became involved with the Navy by accident, strictly by accident. A friend of Admiral Isaac Kidd, then Chief of Naval Material, had known Alan Shepard. Alan came to me one day and said, "Will, the Navy's having an awful lot of trouble with fleet readiness and reliability. I think you should go over there and talk to them a little bit and just see if there's any way you can shed light on their problem." So I went over there one day during lunch and spent some time with them. The result was that I agreed to do a quick study for the Navy--to say to them that if we, NASA, were doing this job, this is how we would be doing it versus how they were doing it. That was the gist of the thing. I took about seven people (this was just before Apollo 17 so I had to hurry) and spent three days on this project. We picked a sample of equipment that the Navy selected and reviewed it at the contractor's site. We reviewed their procurement cycle and their contract. The result was that we told the Navy we just wouldn't have done it that way. "We don't believe that the hardware you get is really going to do the job for you when you do it this way."

As a result of that, I was asked to give a presentation to what the Navy calls the "General Board," which is a large group of the admiralty who gather periodically to pay homage to the Navy. I stood before that group not knowing what was really in store for me. At the end of that presentation, Admiral Kidd said to me, "Will, I expect you to report on board in two weeks." Not being too swift, I thought a minute and said, "The Navy's here, NASA's there; I don't think you can really say that." I smiled and said, "That's a very kind invitation, thank you," and left. The Navy continued insistent, and letters flew back and forth between NASA and the Navy. I can remember vividly when the letters kept coming from higher and higher authorities. Finally, they were on secretarial levels and White House levels. My management came to me each time saying, "What do you want us to do about this?" I said, "Let's use Navy terminology. Let's tighten up the line, let's throw out an anchor; but whatever you do, fellows, don't turn loose of me." I said, "I've seen those guys over there and, believe you me, they couldn't win if they had to." That went on for awhile. Finally, the NASA administrator came to me and said, "Really, I don't know what you've done over there, but you don't have to go to work for the Navy." From that point on, things looked black. I agreed to go on a loan basis for 18 months to see what could be done in that time. My secret ambition in that 18 months was simply to prove that nothing could be done and so go back to NASA.

That, of course, is where a part of the story i want to tell you tonight really lies because Admiral Kidd came back from the fleet at that time. He was new to the Naval Material Command as its Chief. He came back with some very, very deep concerns about readiness, about the Navy's fighting ability. He expressed it to me in many terms, but I think it can best be expressed to you simply that he didn't believe the Navy could do the job with its current state of reliability of readiness. He was very worried. He had been side-by-side with the Russian Navy. He had seen it and he worried. He had come from the Mediterranean. When he saw me fighting coming to the Navy, he asked me to please keep an open mind. He said, "I'll give you access to all the files, the systems, whatever you'd like to have in order to learn and understand what our problem really is."

Early in my life a lead engineer had told me of an equation for success that I've always kept in mind. It came to mind then, and I used it primarily as one of the basis for assessing "Why me?" in the Navy; why couldn't it be somebody else? This equation for success goes something like this.

First, you must know the problem. I went through the Navy files; and as nearly as I could see, they knew the problem of fleet readiness, of unreliability, of trouble with equipment, as long as ten years ago. They couldn't have been after me just to learn the problem. They already knew what the problem was; it's well documented.

The second part of this equation for success is that you must have the proper tools. I looked through the system once again for tools. In this case there would be instructions, procedures, directives, specifications, etc. What I saw there was an abundance; it wasn't a lack.
Later, I came to believe that the abundance I saw was really a part of the problem; it's called a Military Specification. I'd never seen a MIL-SPEC before. (I've lead a sheltered life, you see. I'll explain to you later.) MIL-SPECS were an anomaly in my life. As I look at them more and more, I've become a sworn advocate of stamping out MIL-STDS. They just aren't what they claim to be. As I said, the second part of the equation is tools, and I'd seen them.

The third part of the equation was discipline. In other words, if you know the problem, have the tools, and have the discipline, you'll always succeed. I've followed that all my life and found it to be a very successful, simple equation. When I looked at discipline in the Navy, there's where I got my surprise. In Washington, where I'd worked in NASA, we were across the river from the DOD complex. I could look out my window and see the Navy's bright braids shining in the sunlight, and I could see them smartly marching up and down the streets. Discipline was the last thing in the world that I thought would be missing in the equation. But I did find that discipline was missing, and when I was relating this story to Admiral Kidd one day, he told me to look completely. I decided that the first place to look was in the Chief's own office, to see if he knew how to carry it out, because that's what he's in charge of--Naval Material. I went in to Ike one day and told him two stories which I'll relate to you one at a time.

The first one involved this business of discipline. I said, "Ike, I've looked through Naval Material Command records and I can relate it to you this way--I can remember as a youngster when the Mighty Mo ran aground in the Chesapeake. All they did was to wait for the high tide and float it off again, but the skipper of that ship never saw the light of day again." I also said, "Ike, there's one other thing that's obviously apparent to me. If you run a procurement aground, the only thing that happens to you is that you 'make flag.' That's absolutely a matter of record." Now I don't say that derogatorily. What is really meant is this: The experience for promotion in the Navy comes from operational experience, not experience in Washington. There's not a program manager in Washington that's not anxious to get out of there as fast as he knows how; and he's rated on his ability to fly an airplane, sail a ship, or whatever it is he does from an operational point of view. His stay in Washington is as minimal as he can make it. He doesn't want to be there long, and he knows he's not going to get much of a rating out of his performance in Washington. So when I say he "makes flag," what I really mean is his interlude in the procurement world doesn't in any way have a lot to do with his promotion. It all comes from his operational ability. Following on with this little litany a minute, what I also want to point out to you is a part of the looking that I did.

The focus that the Navy has in front of it today was set by a study I did with three or four people I brought from NASA. We reviewed about 180 contracts. I asked for 180 contracts, at random, of Naval procurements (some large items, some small items, some very small items) and looked through those. From this review we really found the major problem in the Navy's acquisition program. The Navy, today, is committed to change it, based on the visibility of that particular study. Of the 180 contracts, I found three particularly significant things. First, there wasn't one contract that had an enforceable reliability requirement in it. Any reliability requirements in the contracts could not be enforced; not a single one. There were two reasons: First, most of them were stated as goals. Having worked in industry long enough, I can tell you what a goal is. I just love contracts written with goals that say you'll do the best you can and someday you'll get the answer whenever they give you enough money. Watch out for goals because nothing ever happens. That is very quantifiable. Second, those that weren't written in terms of goals were stated in terms of probability and statistics. You have to realize right away that anybody in the Naval Material world who deals in terms of probabilistics is intellectually dishonest. He's fooling himself, and he's fooling everybody because the population size is too small. It just doesn't work. I can give you a point estimate with engineering judgment that has more accuracy e to the minus lambda t carried to nine decimal places with a sample size of 500. It just doesn't work; it's speculation.

But the even more damaging aspect of probabilistics is that they're nonuseful to engineers. Back in the 1950's when I was designing electronics, I can remember when reliability came into vogue. We had never heard of the word. In 1953-55 reliability started popping up. I can remember the lead engineer coming to me and saying, "Will, this has got to be a reliable system here." I said, "Gee, what does that mean?" It was .99, .98, whatever the thing was. I said, "Chief, what does that mean?" He said, "It's got to be good." Probabilistics just don't do you any good; what we want is MTBF. MTBF is a useable item. It's just as useable as volume, weight, space, velocity, etc. But these contracts had none of that in them. So our first observation was that they just weren't enforceable. None of the 180! It didn't matter who you wrote them with, who they were for, what equipment they were for; they just were not enforceable.

The second finding, and equally interesting, was that all the contractors in these 180 contracts gave the Government what it bargained for in performance. As a matter of fact, more than thirty percent of the contractors gave us more performance than we wanted. From a performance point of view, the records that Packard left behind seem to make a lot of sense. You can almost leave a contract alone when it comes to performance. It seems as though we can generally get what we want when it comes to performance.

Out of this contract review came the third part of the equation which is really the one we're going to focus on tonight. Any reliability given to the Navy in the equipment, and any reliability that was achieved, was an accident. It was serendipity. It was what was left over after the performance specification had been set. Any other attempt to put reliability in it was fallacious. It was just somebody picking a number out of thin air and writing it down, without basis. That led me to the real fundamental thing that we're talking about here tonight, and that is that <u>reliability must be a function of design.</u> It can't come by chance. One of the first things I found when I came to DOD is that you have to have a slogan such as "design to cost." There's life cycle cost, all sorts of slogans, so the one we used was "reliability by design, not by chance." The contract review showed that all the reliability that came to the Navy in its equipment was strictly by chance. The program manager primarily was being motivated by performance and a budget and schedule. Most of the time, he was in trouble in some way that you could trace back to the fact that the equipment wasn't reliable. It was taking him more time in the test program, running his budget up, giving him trouble in the fleet. He was having to go out and do some fixing and that was running his budget up. Primarily, though, the schedule/cost/budget problems he was having could be attributed to the fact that reliability was not part of his design. That puzzled me because, you see, in my experience (tracing backwards, before I came to NASA, I was at ARINC) reliability was a first requirement. When I was with the airlines, reliability was a first requirement. I had led a sheltered life because, in every case, reliability was desired and, as a matter of fact, required. In the case of Bell Labs, that was profit and loss and they designed 30 years in MTBF equipment; not 30 hours or 30 minutes. Repeaters that go under the ocean have 35 to 40 years demonstrated MTBF today. Profit and loss: they don't have to pull those things up. Cables are very hard to service; they're trouble. What motivated that design was

profit and loss. With the airlines it was profit and loss again; but in this case, safety was thrown in. The equipment the airlines dealt with had to be reliable; they had to be careful. In Apollo we were in a goldfish bowl and all of us, whether we wanted to or not, became very well acquainted with the astronauts. We loved them like brothers and took extra care simply because of our appreciation of the astronauts. All in all, we were motivated. When I looked at the Navy and their program managers and their procurement system, I saw nothing motivating reliability--not a thing. There is where I saw the root cause of the problem: motivation.

When I told Ike this, he asked me what I was going to do. I said, "The first thing I'm going to do is focus attention on the subject. I'm going to embarass people. I'm going to cause them to take second thoughts and ultimately we're going to require that performance and reliability be given equal consideration in RFP's, in Navy thinking, in the Office of the Chief of Naval Operations, in the whole equation." We have recently begun this in our institutionalizing process. We've issued a reliability instruction in which it is required that reliability and performance be equally considered in every aspect. Do not consider it second. If you can't make it reliable, don't start.

I have a little card in my pocket that I think is down-right amazing. This is called the Realistic story, but it's Radio Shack. In it, Radio Shack has a very interesting paragraph that I think goes for anybody dealing in the equipment world. I found it remarkable for a manufacturer like this to state it quite this way, but this is how they stated it: "Our people who design and build our products approach their task differently from conventional makers. We build to achieve three things in the following order. First, reliability; second, performance; third, competitive price. We're not interested in price unless the product is reliable. We're not interested in price unless the performance meets our criteria for the way things work, look, feel best, and sound." So here's a little manufacturer just making equipment who has a better motto for reliability than I found in the Navy. As a matter of fact, it really fits the motto that I have now brought to the Navy. The Navy has now taken this on board with great vigor.

At first, there was a lot of trouble. We did have a lot of problems in getting it understood. I think the main thing we had trouble with was the snapshot I took of what reliability really meant to the Navy when I went there. It was simply this: measurement, measurement. It was e to the minus lambda t. That was reliability. It was a cultist organization run by statisticians with the engineers completely out of the loop. It was done at the end of the development cycle. Sometimes, it was done after the production had stopped. I saw a squadron of airplanes going on a carrier. They were already on the carrier and production had already been turned off. I reviewed the contract and saw in it a reliability demonstration program: 3.5 million dollars. I said we don't need to spend that money. There's nothing you can do about it; they're already on the deck of the carrier. Why do we want to demonstrate it? The flyers will tell us what it's all about pretty quick. It doesn't take them long. I saw that measurement was what we were primarily doing. Measurement is all right providing it's a closed loop measurement cycle. You have to realize in a military procurement cycle that it isn't closed loop. There's no time for it to be closed loop. If a measurement takes place at the end, then you do not have sufficient money to make the fundamental corrections you should make to the equipment. The time you have for delivery is paramount because contractors who are building ships will charge you for every day the equipment is delayed in delivery to them, so they find themselves in a bind. The equipment comes up for test and, guess what, it's a bust. It doesn't make any difference; they deliver it anyway. I can show you record after record of Navy materials flunking their demonstration tests and being delivered with a fix kit for the fleet. Of course, that's the box you're in and I don't blame anybody for that.

If you wait to that point in time to get your snapshot of what reliability really is, then you've lost the game unless you just happen to pass. In a lot of cases the passing is rigged. I've seen equipment that demonstrated 22 hours MTBF in a six-month scenario of "fleet environment." When it went out to the fleet, it was one-tenth of an hour MTBF demonstrated. Why? Because it really never saw the fleet environment until it got there no matter how hard we tried. I don't think anybody necessarily did it wrong on purpose. It's just impossible to demonstrate that kind of a thing that late in the program. It's got to be in a designer's mind; it's got to be part of the "mission profile" he designs to. That's the way we've always done it in our lifetime. We never waited on a demonstration to do it. What I really saw was that the present approach for reliability was really by chance.

I thought that the only thing we could really do was to start an intellectual discourse with the engineers, with the managers, with everybody involved, as to what they were really doing. We could cause them to start thinking a little bit and see if the thinking process wouldn't really lead them to the right answer. Over the past years, that's what I've done. I issued an instruction in April. I could have issued that instruction when I first came two and one half years ago. Of course, it wouldn't have looked the same as it does today because I learned a little and they learned a little. So together I think they have an instruction that is going to be supportable and which will cause an improvement in our reliability.

Let me talk to you just a minute about that same snapshot involving military standards. I blamed the problem of some of our fleet on military standards. I haven't found a more damaging standard than MIL-STD-781B, which is an environmental test specification for reliability demonstration and acceptance. We're better off to stomp it out, to get rid of it. What I have now promoted is a change to MIL-STD-781C. MIL-STD-781C has a lot of the good things in it I think we ought to have. Military standards aren't really wrong; it's the way we use them. Most people have become so used to boilerplating with military standards that they simply say if I'm

going to have a reliability program, it's going to be in accordance with MIL-STD-785A. MIL-STD-785A tells you how to build everything from bullets to ships. You have to use your mind the minute you see a military specification, to tailor it. There is a paragraph in these military specifications that says to tailor the design to the situation and use what's applicable in the specification, but I haven't seen that done. Most people have gotten into the habit now of just taking the military specification and using it as is, without much intelligence and without much thinking about it. What we've had to do is to pull our reins in on the military specifications in those areas that are bothering us and say "You can't use them unless you come to us and tell us about the military specification you intend to implement; what parts of it are applicable to this design and what parts aren't?"

One of the things I have in my office that makes all this possible (while I was still working for NASA, I did negotiate with the Navy what I considered to be something that was very necessary if we were really going to get on with the job with the Navy) is the authority to carry it out. I have a thing called a business clearance review which simply says that you don't go to contract with Navy unless you go through my office. When those contracts come through, we send them back if they haven't got the right requirements in them and we haven't said the right things. This has caused a little bit of controversy, a little bit of a problem. As I told someone at supper time, you may have noticed that the crime rate in Washington has gone down according to the records. There is no doubt in my mind this is true because the Navy has hired all the hit men out of Washington to see what they can do about me.

There is no doubt we do have a problem which we're trying to solve; part of it being to get attention focused in the right places. The main thing we have found is that combat effectiveness is really a function of economic effectiveness. We're finding that the greatest economic level for reliability improvement in the fleet comes in the design process. It uses less money and involves less time. You can erase a resistor on a drawing board whereas if you replace it in the fleet, it costs you millions and millions of dollars. Without really knowing what I was doing, I recently approved a no-cost Engineering Change Proposal (ECP) to change a capacitor in a piece of equipment that was out in the fleet. When we were done, it cost three million dollars because we had to change publications, training, standards, and test equipment. All I did was approve the no-cost ECP for a capacitor. There is no such thing, fellas. When it gets in the fleet it's a costly process. This is what the Navy is finding out. The economic leverage isn't where it was. That is today, of course, the biggest asset I think we have in helping us get this reliability equation solved--the economics of the budget. We are finding ourselves with a shrinking budget, and we're not able to buy what we could buy before; you have to realize that the large majority of the Navy's money goes into spare parts and product support.

When I first came to the Navy, what worried me most was how to get attention focused on design when by admission of every contractor, his main money making source was parts and support. That worried me greatly. I went out to see a few contractors. Not long ago Harry Graves, President of United Technology, even put it in writing in Aviation Week, that 30 to 40 percent of United Technology's profit structure was parts and support. While that equation got changed (not due to anything I did) because of inflation shrinking the ability to buy with the dollar, what we found ourselves doing more and more was buying less and less new equipment. This means no new starts for the industry. This means a technological base freeze, literally. We just can't do anything new; all we can do is support what we've got. In briefing industry, I have called their attention to starting to design for reliability now if you intend to keep a technological base because it's going to stop. We're just not going to buy any new equipment. If you look through the Navy's records, you will find there is very little new equipment being bought. Most of it is reprocurement and update of old equipment. There is some new equipment, of course, but not nearly to the extent we ought to have. We have set into being what we call a "new look," a new way of doing business. In that new way of doing business, we've published a little thing for public relations or public information. It says in one word what the Navy is going to do. It says what you must do in terms of RFP's, bids, designs, etc. It says to contractors that unless you follow these, you're just not going to do business with the Navy. At first there was a little doubt about that, but it soon went away. We have it pretty well understood now that this is the method by which we're going to do business. As I said before, the biggest thing we have to do is get the reliability decision-making process up early. We have to decide if it's going to be a reliable device early in the design. We have to lose this infatuation with performance.

The commercial industry has lost its infatuation with performance. When you go out to buy something in the commercial world or your wife goes to buy something, you don't ask how many times the washing machine jiggles up and down or what kind of a defrosting cycle your refrigerator has, etc. The main thing you ask the commercial industry is whether it's durable, is it reliable, how long will it last? You've seen the ad for Maytag washing machines where the poor maintenance guy is just out of business and crying because he has nothing to do (a little exaggerated because I own one). Nevertheless, in principle, it is focused about right. They have done a good job. The RCA XL-100 is a good example, and I happen to know that RCA didn't get there by accident. That set was held off the market for quite awhile while they worked on limited life. I don't know whether you have had any bad experiences with them or not, but the basic concepts are there. Most of the industry is trying to work on a product life. The only people who aren't working on it right now (who weren't working on it, I should say) is the Navy. We're working on it right now. The new approach says that we are going to design it in and we are going to make sure that the concepts have been considered early in the game. The reason we want to do this is to reduce what

Admiral Kidd called an "umbilical to the beach."

I stand here tonight and very sincerely say to you that I worry in terms of our defense posture with the U. S. Navy after having seen some of the Russian technology through the Soyez Visibility. I have come to a personal conclusion I want to express to you tonight. The thing that motivates me to continue under all the stress and duress in the Naval Material Command is to make sure that this project does get carried out and that the Navy does change its way of doing business. I'm motivated simply by this: I'm convinced that our sophistication is the problem we have in our equipment. The Russian technology is not very sophisticated; it is very unsophisticated equipment. If you simply take a quick snapshot of what that means if the two forces were engaged, you have to come to the following conclusion: If it's a short engagement we would be the superior; if it's a long engagement, I think we'll have a problem. Sophistication without life gives you only the original big bang. For instance, we can have a plane that can leave an aircraft carrier and go do a mission and come back, but he can't do it twice. Oh, I may rectify it while he's down; however, some of their equipment can go up over and over and over again. They can't do as sophisticated a mission and they can't track multiple targets, but the point is that they have the sustaining power. What I'm dedicated to doing is seeing that this performance, which is so good, also has life. If you put life into our performance equation, it's unbeatable; it's absolutely unbeatable. When things get tough and I get tired, I always reflect back to that particular snapshot that I had and I come on again with new vigor to see to it that we carry out this new Navy program.

In order to do that, we've also created another slogan which we call "Big R, Little m." In other words, we want reliability in our equipment and we want it to have minimum maintenance because I saw in my snapshot of the fleet that our maintenance problem is truly bad. It's tough. I went out on the carrier, the AMERICA, and before I knew the Navy's reliability problems were for real, I even agreed to fly in an F-14. It was only later that I woke up to my indiscretion. Since this is a technological symposium, let me tell you something. The Navy does do things they don't take credit for. I am completely convinced that the Navy has invented the elusive time machine that everybody talks about. When I went on the F-14, while we were sitting on the catapult waiting to leave the deck, the pilot up front gave the catapult officer a salute; and he said to me, "Will, if you're comfortable back there, you give a thumb's up." While we were sitting there on the catapult, the pressure was raised, the engines were run up, the pilot gave his salute, and I raised my thumb. Even though only one second passed, it seemed like days because I looked at that finger and said, "You fool, what have you done?" It was a valuable experience. I learned a lot.

What I saw out there were tired people, maintenance people who had lost their enthusiasm for maintenance because, as one fellow said, "It doesn't do any good to repair it; it'll be back the next day." I put an "X" on the box and said let's look at that one when you're done. He finished testing it; I stood right there and said "Okay, I'll put my initials right here." I told him I'd be back tomorrow night. I went back the next night and he was grinning. There it was. This is bad motivation for maintenance people. How would you like to keep repairing something over and over again and just see it fail, see it come back. Pretty soon you just have an "I don't give a heck" attitude. I am also dedicated to helping those fellows change their attitude because, as I told them, they're our stewards. We dedicate that equipment to them and yet part of what we give them is junk, just pure junk. We say to them take care of it, treat it right. You and I wouldn't buy it if we went to the marketplace to buy some of that equipment; it would never get sold because we know better. What we have done is to emphasize reliability by design. We've now brought the process up to the front end of the contract and said "Measurement is not very important any more." We are going to have measurements for contractual reasons; there is no way a contractor can be released unless he has demonstrated he did what you asked him to do. What we're not going to do is make decisions based on that measurement data. We're simply going to release him from his obligation if he did the demonstration like he was supposed to, and we're not going to put a lot of bucks in it.

Instead, we are transferring the money up to the front end of the contract and we are asking them to do things that are on this particular card. This little card was really made as a flyer for the instruction that came out so that some people who didn't want to read the whole instruction could see it right here on one card. In this thing, we have the requirement "design to minimize failure." That is really what it is all about. First of all, you have a mission profile which is a Navy responsibility. This one you don't lay at the feet of the contractors. Most of the equipment I saw in the Navy didn't have a fighting chance because no one had said what the mission profile was going to be. We had simply told the contractor to make it so it will operate in some unknown environment for some unknown number of cycles. He can't do that. The designer must know what you intend to do with the equipment, how you intend to use it. We have had a very difficult problem getting this ironed out, but we finally got the specifications, etc., out, and people are responding to the mission profile. Some of them are a little weak, but they are getting better. For a while I didn't think I had a chance, to be honest with you. It looked like it just couldn't be done. I've seen responses in the last year that have shown that people are starting to think and are recognizing the same thing I recognize. If we do want a Navy, we want it to be a good Navy. Therefore, we have to put some time into product life. We have also said that we want you to do environmental profiles. We want to know the environment in which the equipment is going to be operating. We want not only the performance profile, but the environmental profile. Following up on that, we are now asking the contractor to give us a design that is understressed, not overstressed. Reliability is simply a function of stress. Once you realize that, there is nothing else to the problem. All you have to do now is figure out a way to solve it.

Reliability is a function of stress, so in order to get the stress levels understood and to minimize the stress on equipment, we have set standards. We have said you will derate all of your components to our standards and we have the list of standards you will use. For instance, we have set junction temperatures inside of semiconductors. A junction temperature is what governs the life of a semiconductor. For every ten degrees you derate a junction temperature, you double its life. In studies they did years ago, NASA and Bell Labs set certain junction temperatures. Bell Labs' junction temperatures run between 50-60°C. NASA said because of weight limitations, space environment, etc., we must have 100°C junction temperature. Would you care to guess what I found the Navy's junction temperatures to be running. They were 170-240°C. Just remember that for every ten degrees you double the life of the device. Just like a light bulb, you cannot stress it too hard. What we have now done is said to the designer, "We want you to follow our derating criteria; we want you to follow our design criteria, but we also want you to make stress analyses." It's funny that you talk about nondestructive testing here, and yet for some reason your electronic community has known for years that electrons running through the wires are just as damaging to components as cars are to bridges. I could find reams of mechanical stress analyses for all the equipment we bought, but I couldn't find the first piece of data for electronic stress analyses. It is very well known and understood.

We have told the contractor to make a stress analysis on every decision, mechanical and electrical. Not only that, we will sit down and review it to see if he did it right. Now there lies the hooker because the Navy has to be able to review it to see if it is right. We do have the manpower and the talent, and we must run them together right now to see that it all gets done properly. We've also done sneak circuit analysis which NASA originated. It isn't too well known, but it is a very worthwhile tool for understanding what stresses you have on your circuits. I'll give you an example of one that you may have in your automobiles right now. I will give you two because I just read another one from Detroit the other night.

A sneak circuit is an unplanned event that takes place due to a malfunction in a component part or a misoperation which opens up a path that had not been normally analyzed to be there. An example is in your automobile. If you own a 1975 Ford or General Motors product, here's a sneak circuit. You know that when you get in your car and your ignition is turned off on the post, nothing will happen when you turn on your radio because you haven't got the column turned on. What you have to do in this case is to turn on your radio, leave the column turned off, reach underneath the key and pull out the emergency flasher (the thing that makes all sorts of lights go on your car). Now put on your brakes and your car radio will play. That's a fact! I've had people rush out and run back in while I was talking to them and say yep, that's right. That's a fact!

Yesterday I read another one that says all owners of Cadillacs are asked to bring their Cadillacs back in. (I'd say anybody that owns a Cadillac deserves it.) All Cadillac owners were asked to bring their cars back in to have a printed circuit board replaced. If you have an electric door lock on your Cadillac, when you move the transmission from neutral into drive, it pulses it into the unlocked position. Now you're asked to bring it back and they'll give you another PC board. In the technical note it says that it keeps the electrons from being confused. Well, they're right. The electrons do become confused.

All I was trying to summarize here in this little bit on reliability by design is simply the fact that it's the place where the money is to be made in the world today if you're interested in seeing to it that reliable systems are brought on board. There is another part of this that worried me; and because I talked about it too much, I found it in my shop not too long ago. I got a call from Admiral Michaelis one night and he said, "Will, we've been listening to what you've said and we've decided to give you that responsibility too." There are a lot of indications that we are having success in the design world, but the thing that I'm worried about now is quality assurance, or quality control. What I'm worried about is whether it's built to print. I've worked in plants where we would do the thing right in design, but it wasn't built like that. I thought it was in another shop and it was, but it just simply melted into mine. Maybe I should not have said anything, but I had a very sincere motivation. You can design it right, but if you don't build it to print you've got a problem. I saw all the indications that our build-to-print visibility wasn't working very well. I went out to contractor's plants (with them kicking and screaming), picked up boards, and brought them home just to show defects on them, to the Material Command personnel, to let them know what we've got to worry about. That's another part of the equation: build-to-print. I now have reliability, quality, maintainability, production and engineering. I don't know quite how to handle all that yet because my focus is still on reliability which I think is the principal problem the Navy is facing.

In closing, let me give you a little bit of insight into some of the things I think would interest you tonight. I said earlier in my opening remarks that I was going to give you some snapshots of what I thought was an exciting period in the Navy right now and what it meant to nondestructive engineering and nondestructive testing. In this world today I see that reliability has to be the focal point of just about everything for awhile because there are a lot of things happening in the world that aren't in the Naval Material Command. We've seen what happens in coal when fuel and gasoline, fossil fuels, etc., start to get scarce. I see that we are also going to find a scarcity of some of our natural resources. Not long ago, Don wrote a paper that elegantly put that in perspective. It says something like "At the current rate of use, we have 40 to 70 years before our natural resources are gone." Why? Because we're in a throwaway society. Because we're at a place where reliability hadn't been understood; but in some of the lesser complicated

things where a lot of money is being spent, it is understood; but in some of the lesser complicated things, we tend to build anew. We say throw it away. I'm raised with a mind that tells me that isn't the right way to do business. Waste not, want not. I learned that years ago, but I find that today's society may be cultivating something that is going to cause us want later on. We haven't focused on the fact that reliability is an important equation in any design, and I'm pushing it very hard. The fix-the-fleet business, as the Navy calls it, is a serious problem for me. I don't like to see them waste all that money going out there and fixing the fleet. It costs millions of dollars to fix something in the fleet when we could do it very cheaply when we're designing it. I am reminded of something here that I'd quickly like to tell you on fix-the-fleet. It's a story that I think will emphasize it to you very carefully.

At one time, this town had what was known as the town drunk. The wife of this particular person was very much embarassed over the situation, and for a number of years she tried to convince Charlie to go on the wagon and stop drinking. Finally, he accepted the challenge. For a long time he stayed on the wagon until one night he went out with the boys. They convinced him to have a few, and then he knew he was in trouble. All the way home he devised a plan for how he was going to get into the house without his wife knowing he had been drinking. He very carefully devised a plan. He went up to the front door and looked and listened. The house was quiet, no lights were on, so he said okay, I can get in the house. If I can get in the house without her hearing me, I'll be all right. He got in the front door, stood in the hallway, and everything was quiet. Then he had a set of stairs to go up, and he decided that the best way to go up the stairs was to take off his shoes because then he could go up more quietly. He took off his shoes and started up the stairs. Being in his stocking feet and with the stairs being a little slippery, he fell. When he did, he had a bottle in his pocket and it cut his north side right badly. So he got up again and listened and everything was quiet. He said well now, I'll just go in the bathroom and patch myself up and I've got it made. So he goes into the bathroom, opens up the medicine chest, gets out the bandaids, backs up to the mirror and fixes himself up. He goes on to bed very quietly, turns out the light, and his wife hasn't heard him because she was asleep. He says, I have it made; she didn't know. The next morning she gives him holy hell. She wants to know why he'd been out drunk last night. He said how could you possibly know I was out drunk last night. She said why else would those bandaids be all over the bathroom mirror? I submit to you tonight, even though you're laughing, that when we go out to the fleet, we're putting bandaids on the bathroom mirror. That is what we're trying to stop. We don't want any bandaids on the bathroom mirror.

Part of the problem has been the staying power within the Navy which has caused this to happen. I happen to be the focal point for this in the Navy. I know it so well for the simple reason that about a year after I was there, as I was going out of my office to see Ike Kidd a minute, I saw a piece of paper on the hall floor which I reached down and picked up. It was a little square sheet of paper that had my name across the top and had a matrix on it. There were a lot of numbers written on it and dates, etc. I said to myself, what in the world is this? I went in to see Ike. When I was there I said, "Hey, I found this on the floor. What is this, Ike? Do you know what it is?" He looked at it a minute and broke out laughing. He said, "Well, this is an anchor pool." Now I don't know if you know what an anchor pool is, but I didn't. The Navy has a custom; when a ship goes into a harbor, you make wagers on the exact time (day, hour, second, whatever) that the anchor goes over the side; and the one closest to the exact time collects the pool. I said, "Well, that's interesting, Ike; but what's that got to do with me?" He said, "This is an anchor pool on when you're leaving." That wasn't too bad until several days later when I got a telephone call. The telephone call went like this. The caller wouldn't identify himself, but he wanted to know if I knew there was an anchor pool out on my leaving. I said yes; it has come to my attention several times now. He said, "I just wanted to know if you'd do me a favor. If you plan on leaving in the month of May, would you make it on the 23rd?" I haven't seen any anchor pools lately because I think people have taken me more seriously. I believe the Navy has mustered its best effort. I believe they really are charging on down the right road now. I believe we have a few years before we are going to get there; but we are going to get there. There is no doubt in my mind about it. I am determined to see it through, and I think it takes determination to see it through. I have had an experience in my life that gave me an awful lot of determination.

In the early 1970's, the doctors told me I had three months to live. I was diagnosed as having cancer, articular cell sarcoma. They said, "That's such a fast disease you won't even make it around the corner." Through the good Lord and the science of medicine, I am still here today. I haven't got all my health back, but enough that I am satisfied.

The point I am trying to make is that this is a part of what I am determined to do. I am determined to see the Navy get what they want because they want it so badly. Sure, there are forces that try not to let it happen, but it is going to happen.

I want to give you one more illustration. It has been a long road over the past four years, and it has been a long hard road. With the issuance of that instruction, I now see that there is some light at the end of the tunnel. To illustrate it to you in a more remarkable way, I would like to tell you the story of the farmer who crossed a chicken with a cow. When he crossed a chicken with a cow, he got a funny looking animal. They couldn't figure out what to call the animal; so the son of the farmer said, "We ought to call it a raribird. It's an unusual looking animal." Through the years they were raising the raribird; they kept feeding it and feeding it; and it got bigger and bigger. Finally, they discussed the matter one night and said, "We've got to get rid

of this raribird. It's just eating us out of house and home." They tried to figure out just how they would do this. Finally, they devised a plan to take the raribird to a cliff. They put him in a truck one night, drove to a cliff, and said, "We're going to push the raribird over the cliff." They pushed and pulled and tugged, and the raribird wouldn't get out of the truck. While they were doing that, the kid said, "I know what we've got to do. We've got to get a big stick so we can tip this fellow out of here. We've just got to pry him out." While the kid had gone to get the stick, the farmer's neighbor came up and saw the raribird in the truck. He walked up to the edge of the cliff and asked the farmer what he was going to do. The farmer said, "We've got to get rid of this raribird. The kid has gone to get a stick so we can tip him out of the truck and push him over the cliff." Then the farmer's neighbor looked up at the raribird, looked over the cliff and said, "That's a long way to tip a rari."

Gentlemen, it has been my pleasure to be here tonight to talk to you and to try to share with you a little enthusiasm. I believe the Navy does have enthusiasm for what they are doing. I know I have enthusiasm for what I am doing. I believe that reliability is an integral part of nondestructive engineering; and I believe that you play a large part in that equation because it is through you that we have assurance of our product. I believe that if you are fighting a tough road, join the crowd. Any time we try to change man's mind, try to introduce new thought, we automatically have a problem and it takes time. I submit to you that from what I have heard tonight, and from what I have read of your proceedings, you are making progress. I believe that if you continue, you will get there. When you do, I am sure we will have a more reliable product; and we, in the Navy, promise to support you. Thank you.